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<b>(21) International Application Number:</b> PCT/IB99/02032 <b>(22) International Filing Date:</b> 21 December 1999 (21.12.99) <b>(30) Priority Data:</b> 98/11764 22 December 1998 (22.12.98) ZA <b>(71) Applicant (for all designated States except US):</b> DE BEERS INDUSTRIAL DIAMOND DIVISION (PROPRIETARY) LIMITED [ZA/ZA]; Seo Building, Corner Crownwood & Booyens Reserve Roads, Theta, 2001 Johannesburg (ZA). <b>(72) Inventor; and</b> <b>(75) Inventor/Applicant (for US only):</b> CULLEN, Barry, James [IE/IE]; 75 The Paddocks, Westbury, Corbally (IE). <b>(74) Agents:</b> HOOPER, Anthony, Robert, Lloyd et al.; Spoor and Fisher, Rochester Place, 173 Rivonia Road, Morningside, Sandton, P.O. Box 41312, 2024 Craighall (ZA).		<b>(81) Designated States:</b> AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).  <b>Published</b> <i>With international search report.</i>
<b>(54) Title:</b> CUTTING OF ULTRA-HARD MATERIALS  <b>(57) Abstract</b>  The invention provides the use of a slab laser beam for the cutting of an ultra-hard material such as PCD or PCBN.		

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## CUTTING OF ULTRA-HARD MATERIALS

### BACKGROUND OF THE INVENTION

This invention relates to the cutting of ultra-hard materials.

Ultra-hard materials are those which themselves have a high hardness, e.g. particles which have a hardness of about 10 or more on the MOHS hardness scale, or materials which contain such particles and have a similar hardness. Particular examples are natural or synthetic diamond and cubic boron nitride, or polycrystalline diamond (PCD) or polycrystalline cubic boron nitride (PCBN).

Ultra-hard materials, particularly those of synthetic nature, can be produced in relatively large sizes and need to be cut for various applications. For example, PCD can be produced in the form of a large disc and this disc needs to be cut into smaller pieces, such pieces having application, for example, as drill or cutting inserts. Further, diamond plates produced by chemical vapour deposition (CVD) are cut into smaller pieces for use as heat sinks for semiconductor devices or in mechanical applications.

Various methods have been used in the past for cutting ultra-hard materials. Examples of such methods are spark erosion and laser cutting. Laser cutting has traditionally used rod lasers which have the disadvantage that damage to the ultra-hard material generally occurs. This damaged material has to be subsequently removed. This removal adds to the expense of producing a product from the ultra-hard material and is wasteful of the material itself.

### **SUMMARY OF THE INVENTION**

According to the present invention, a method of cutting an ultra-hard material includes the steps of using a slab laser beam to effect the cut. By "ultra-hard material" as used herein and in the claims is meant a particle which has a hardness of about 10 or more on the MOHS hardness scale, or a material which contains such particles and has a similar hardness. Particular examples of such materials are natural or synthetic diamond and cubic boron nitride, polycrystalline diamond (PCD) and polycrystalline cubic boron nitride (PCBN).

### **DESCRIPTION OF EMBODIMENTS**

The invention uses a slab laser. A slab laser may comprise a slab of material having parallel, elongate faces and end faces which are each cut to define a brewster angle. The laser beam enters and exists across the brewster angle end faces and undergoes total internal reflections on the two parallel, elongate faces. This reduces the thermal distortion and lensing effect leading to reduced beam divergence. Restricting the laser to oscillate in TEM<sub>00</sub> mode only further reduces the beam divergence. This results in a 'sharper' more parallel beam with greater depth of focus which is beneficial to precision laser cutting of ultra-hard materials. In addition, the greatly reduced beam divergence means that a smaller spot size (focussed spot) is possible.

It has been found that the use of a slab laser improves cutting efficiency and reduces damage to the ultra-hard material. Thus, a higher yield of smaller products or pieces from the material is possible than when using a rod laser. A slab laser further allows for better heat distribution and lower power use.

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The use of a slab laser has application in any ultra-hard material, particularly a backed or an unbacked PCD or PCBN. A backed PCD or PCBN comprises a layer of PCD or PCBN bonded to a substrate or support which is generally a cemented carbide. The cemented carbide may be any known in the art such as cemented tungsten carbide, cemented titanium carbide or cemented tantalum carbide.

In use, the slab laser may be used to produce a cut completely through the ultra-hard material producing two or more separate pieces. Alternatively, the cut may be only partially through the material, from one or both sides.

The invention has particular application to the cutting of backed or unbacked PCD or PCBN. It has been found that the slab laser on cutting through the PCD or PCBN allows for weak graphite or hexagonal boron nitride bonds, as the case may be, to be formed leaving a weakly bonded structure. With carbide backed PCD or PCBN, weak carbide bonds are also formed in the carbide backing. Further damage to the PCD, PCBN and carbide backing is less with slab laser cutting when compared with rod laser cutting.

In an example of the invention, a carbide backed PCD product sold under the trade mark Syndite® was cut both by a rod laser and by a slab laser. The conditions used are set out in Table I:

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TABLE 1

YAG TYPE	ROD	SLAB
Beam divergence (mrad)	2,0	0,34
Mode	Multimode	TEM <sub>00</sub>
Pulse width (ms)	0,5	0,26
Pulse energy (J)	1,53	0,48
Average power (W)	75	20,02
Peak power (kW)	3,06	1,85
Repetition rate (Hz)	49	41,7
Cutting speed (mm/min)	45-50	10
Focal length of lens (mm)	80	100
Beam expanding telescope ratio	x3	X2
Focussed spot size (μm)	70 (minimum)	70 (20 minimum)
Assist gas	Air.	O <sub>2</sub>

The laser damage created by both forms of cutting was compared and the results thereof are set out in Table II:

TABLE II

	ROD	SLAB
Depth of carbide damage ( $\mu\text{m}$ )	>100	50
Depth of PCD damage ( $\mu\text{m}$ )	<50	<50
PCD cracking ?	Yes	No
Width of damage to polished PCD surface along cut edge ( $\mu\text{m}$ )	60	30

The difference in damage between slab and rod laser cut Syndite® pieces can be assessed in other ways. First, the destructive or permanent damage when using a rod laser results in the PCD layer being very susceptible to cracking. Cracking can render the cut piece commercially useless. The type of cracking created by rod laser is almost certainly caused by thermal stress which puts the surface of the PCD in tension on cooling. In contrast, slab laser cutting uses a much lower level of power which results in reduced thermal stress and no observable cracking in the cut pieces. Second, another type of damage is surface and sub-surface damage, i.e. damage which can be removed but reduces cutting yield and increases the cost of tool fabrication. With rod and slab laser cutting, there is a clear difference in the carbide substrate after a 0,05mm edge grind. In the pieces cut using a slab laser, the carbide substrate is clear and free of damage. In contrast, pieces cut using a rod laser exhibit a "crocodile skin" effect in the carbide substrate. A "crocodile skin" effect is a heat phase cracking and is a hard brittle skin on the carbide that has to be removed before the piece can be used to fabricate a tool. It is estimated that

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using a rod laser the effect extends back 0,1 to 0,15mm from the cutting edge. With a slab laser, the effect, if at all, extends back less than 0,05mm.

The use of a slab laser beam also has several advantages over conventional wire EDM cutting of backed and unbacked polycrystalline products. For example, there is less damage to the polycrystalline products and support or substrate, there is a significant increase in the cut product, the necessity for post-cutting treatment to restore edge quality is reduced, there is less leaching of metal from the support and less edge undercutting.



**CLAIMS**

1. A method of cutting an ultra-hard material includes the steps of using a slab laser beam to effect the cut.
2. A method according to claim 1 wherein the ultra-hard material is PCD or PCBN.
3. A method according to claim 2 wherein the PCD or PCBN is bonded to a substrate.
4. A method according to claim 3 wherein the substrate is a cemented carbide substrate.
5. A method according to claim 4 wherein the damage to the carbide caused by the laser cut is less than 50 $\mu$ m.
6. A method according to claim 1 and substantially as herein described.

# INTERNATIONAL SEARCH REPORT

International Application No  
PCT/IB 99/02032

**A. CLASSIFICATION OF SUBJECT MATTER**  
IPC 7 B23K26/00 B28D1/22

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
IPC 7 B23K B28D C03B E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 567 129 A (SUMITOMO ELECTRIC INDUSTRIES) 27 October 1993 (1993-10-27)	1-3,6
A	column 1, line 1 - line 8	5
A	column 6, line 33 - line 34; figure 1	
A	PATENT ABSTRACTS OF JAPAN vol. 017, no. 192 (E-1350), 14 April 1993 (1993-04-14) & JP 04 340282 A (ISHIKAWAJIMA HARIMA HEAVY IND CO LTD), 26 November 1992 (1992-11-26) abstract	1

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☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p>PATENT ABSTRACTS OF JAPAN vol. 012, no. 496 (C-555), 23 December 1988 (1988-12-23) &amp; JP 63 206386 A (RES DEV CORP OF JAPAN; OTHERS: 01), 25 August 1988 (1988-08-25) abstract</p>	3

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/IB 99/02032

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0567129 A	27-10-1993	JP 6040797 A	15-02-1994
		DE 69313709 D	16-10-1997
		DE 69313709 T	08-01-1998
		RU 2094225 C	27-10-1997
		US 5483038 A	09-01-1996
		ZA 9302810 A	17-08-1994
JP 04340282 A	26-11-1992	NONE	
JP 63206386 A	25-08-1988	NONE	